

# Spray Dryer Absorber Design

## SDA Features:

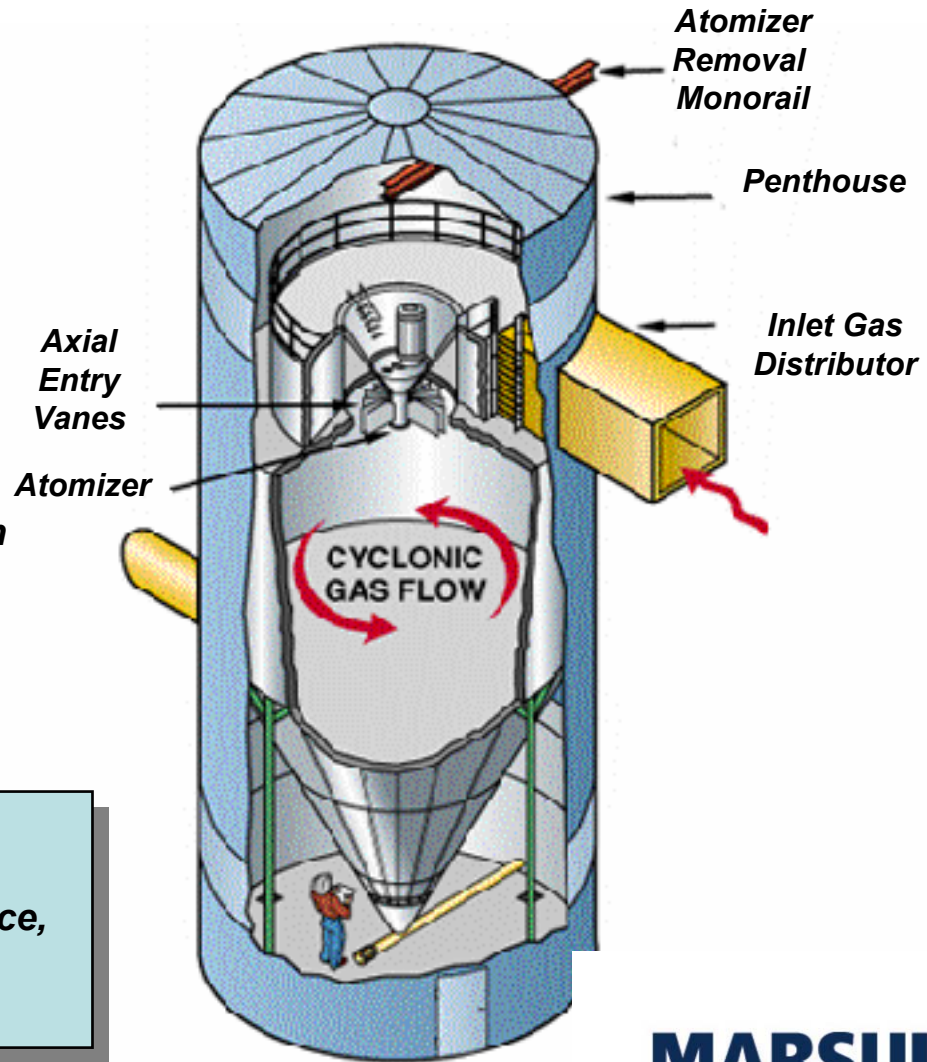
### Single Atomizer / Single Gas Inlet

- **Symmetrical flow**
- **Simple gas distribution / turn down**
- **Complete gas / slurry mixing**
- **Elimination of wall buildup**

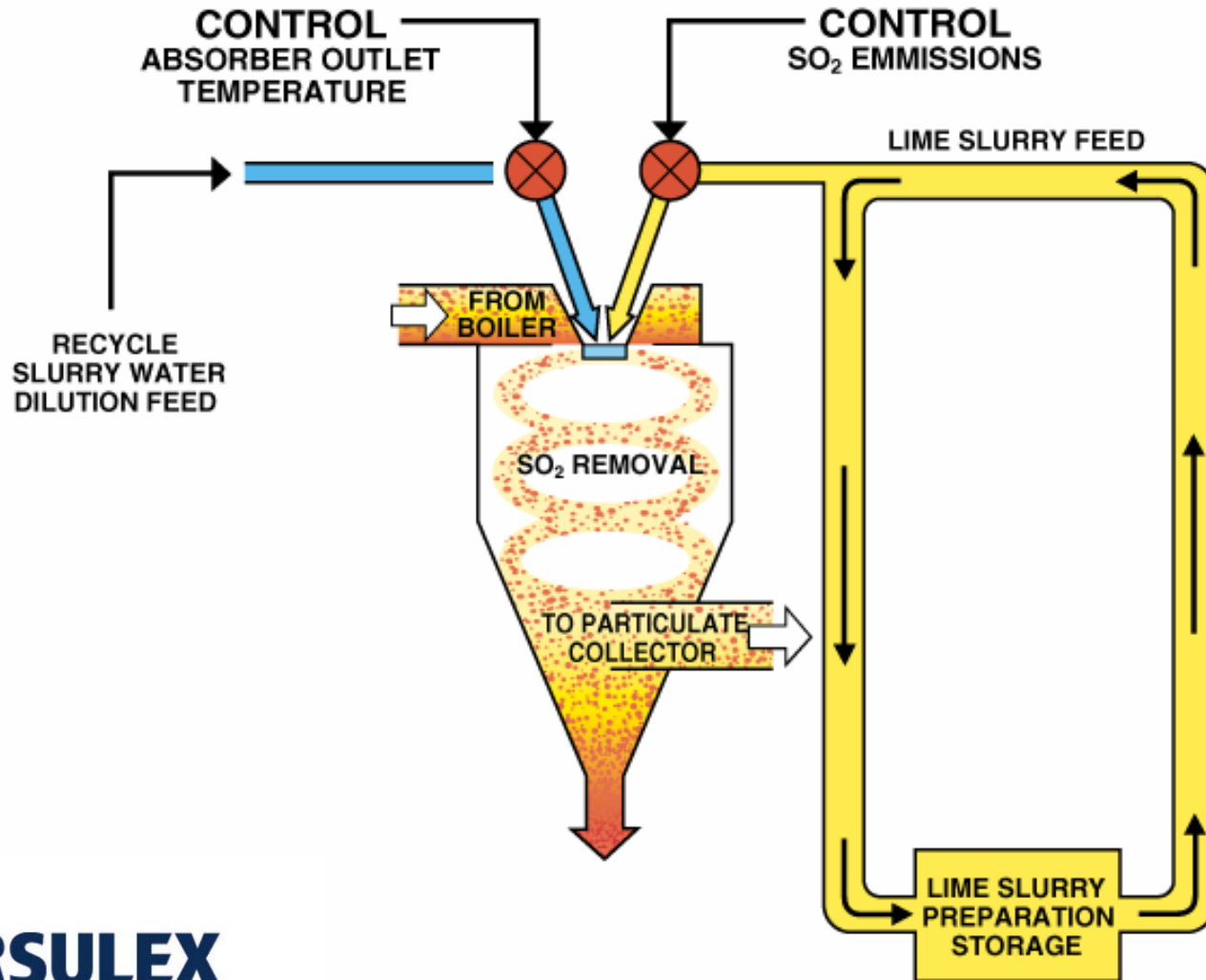
### Cyclonic Flow / High Exit Outlet Design

- **Particulate dropout: 10 – 20%**
- **Reduced outlet dust loading**
- **Optimized system pressure drop**
- **Protection during upset conditions**

**Design Simplicity and Symmetry  
Result in Higher System Performance,  
Flexibility and Reliability**



# TWO LOOP CONTROL



# Atomizer Design

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## **Rotary Atomizer**

- *Demonstrated technology by MLX & Anhydro*
- *5 HP to 760 HP units in operation*
- *Over 3,000 atomizer installations*

## **Reliable & Low Maintenance Drive Systems**

- *Flat belt drive up to 200 HP*
- *Variable speed direct drive over 200 HP*
- *Speed variation simple and flexible*

## **Lubrication System**

- *Once-through oil mist*
- *No special filters, coolers or recirculation pumps*
- *Maximum bearing service life*

## **Key Material Selections**

- *Stainless steel for wet slurry contact*
- *Solid stainless steel or C276 alloy atomizer wheel*
- *Silicon carbide nozzles and wear tiles in atomizer wheel*

***Demonstrated Atomizer Technology Applied  
To DFGD & Waste Incineration Applications***



# ***Rotary Atomizer Selection Summary***

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<b><i>Application</i></b>	<b><i>Model</i></b>	<b><i>Drive System</i></b>	<b><i>HP Range</i></b>
<b><i>FGD &amp; DAGS</i></b>	<b><i>CF-250</i></b>	<b><i>Flat Belt</i></b>	<b><i>25 – 75 hp</i></b>
<b><i>FGD &amp; DAGS</i></b>	<b><i>CC-400</i></b>	<b><i>Flat Belt</i></b>	<b><i>75 – 200 hp</i></b>
<b><i>FGD</i></b>	<b><i>CD-400</i></b>	<b><i>Direct Coupled</i></b>	<b><i>200 – 425 hp</i></b>
<b><i>FGD</i></b>	<b><i>HCA-400</i></b>	<b><i>Direct Coupled</i></b>	<b><i>425 – 800 hp</i></b>

*FGD – Flue Gas Desulfurization*

*DAGS – Waste Incineration Dry Acid Gas Scrubbing*



## ***Model CD-400 Atomizers w/315 KW Motors in Maintenance Stand***

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***Wet FGD Technology***  
***Advanced Ammonium Sulfate***



## ***New Market Factors Drove Ammonia Technology Development***

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### ***Emissions trading mechanisms created new “competition”:***

- *USA’s Clean Air Act Amendments of 1990 created “emissions trading” mechanism;*
- *Utilities’ true cost of SO<sub>2</sub> emissions, absent local or extraordinary regulations, became “the value of credits on the market”;*
- *Credits reached relatively low levels of approximately US\$ 63 per ton in the 1990’s;*
- *This low cost of “compliance” established a very high, competitive “bar” for conventional FGD technologies;*
- *A new approach was needed, one which could compete with low emission credit values;*

***Marsulex (then General Electric) developed and commercialized an improved version of ammonia scrubbing technology;***

***Marsulex’s Ammonium Sulfate FGD Technology  
Meets the Competitive Challenge  
by Lowering Compliance Costs***



## Ammonium Sulfate Process Chemistry

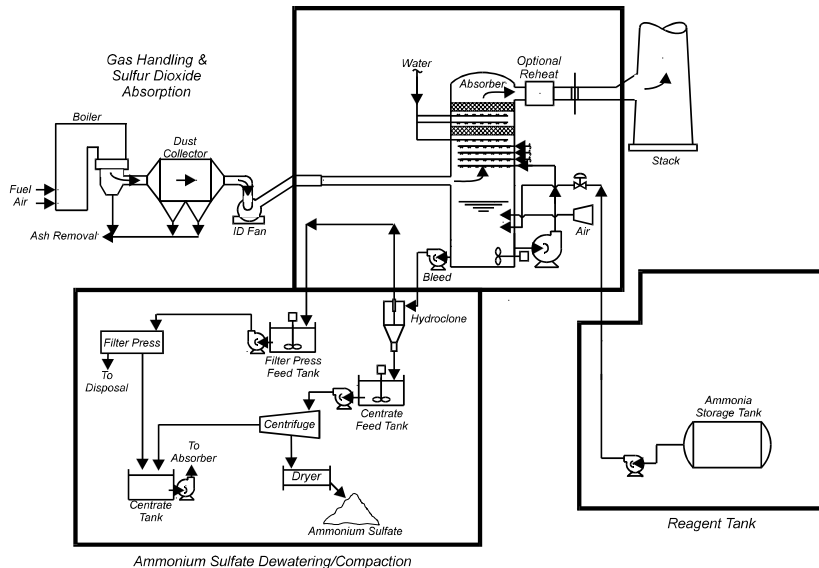


- For every kilogram of  $\text{SO}_2$  removed:
  - Need one-half kilograms of Ammonia
  - Produces two kilograms of Ammonium Sulfate
- One tonne of Ammonia generates four tonnes of Ammonium Sulfate

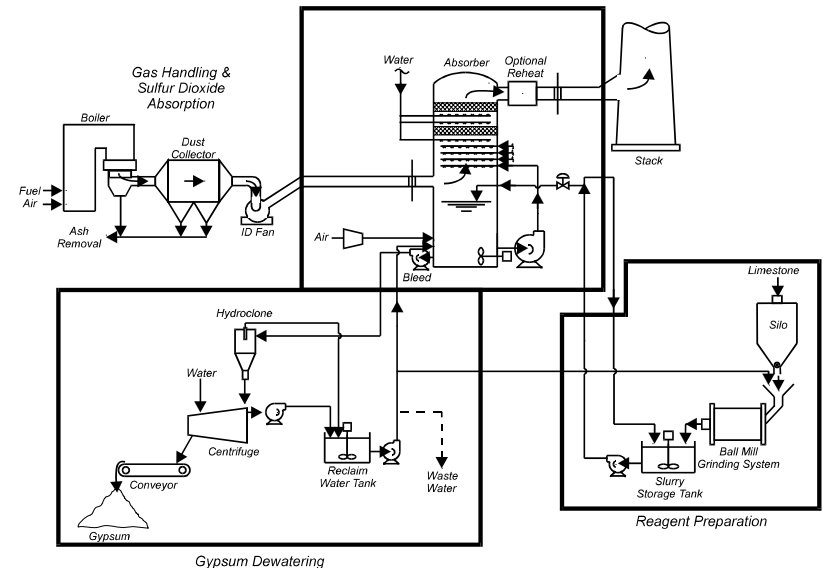
**Economic leverage derived from the 4:1 production ratio between ammonium sulfate and feed stock ammonia**



## Ammonium Sulfate Process



## ***Limestone/Gypsum Process***



### ***Based on Proven Equipment - Different Reagent***

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## ***Ammonia Scrubbing Basis of Design***

### ***First Generation Ammonia Systems***

- *First Attempts At Ammonia Scrubbing Utilized High Ammonia Reactivity Resulting in Very Aggressive Absorber Designs - pH, L/G, Absorber Size*
- *As a Result, Early Generation Ammonia Scrubbers Resulted Very High Ammonia Slip and High Opacity Issues*
- *Higher pH's and Incomplete Oxidation Produce Free Ammonia in the Gas Phase*

### ***MET Ammonia Scrubbing Process***

- *MET Demonstrated and Patented Optimum Operating Range to Minimize Ammonia Slip And Opacity*
- *Free Ammonia in the Gas Phase Determines opacity Levels and is a function of Three Process Parameters; pH, Degree of Oxidation and Ammonia Injection Methods*
- *MET Demonstrated Minimal Gas Phase Ammonia and Zero Impact on Opacity From Ammonia and Ammonium Salts*

***Essence of MET Patents Ensures Operation In Optimum pH Range, Complete Oxidation and Optimum Ammonia Injection Methods***



# Ammonia Scrubbing Technology Summary

## Ammonia Scrubbing Development History:

- 1985-87 Developed bench-scale ammonia scrubbing technology
- 1987 GEESI awarded first ammonia scrubbing patent
- 1992-93 10 MW pilot demonstrated for two modes of operation
- 1994 Awarded commercial contract with DGC
- 1994 Second ammonia scrubbing patent awarded
- 1996-97 Startup and successful demonstration of 350 MW eq. Ammonia scrubbing with production of granular ammonium sulfate
- 1997 Marsulex purchased substantially all the assets of GEESI
- 1998 Applied for three (3) additional patents

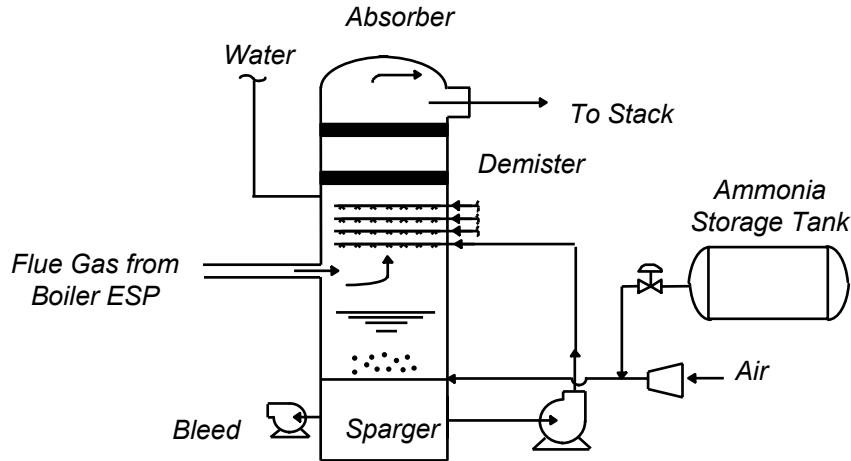
## Commercial NH<sub>3</sub> System Performance at DGC:

Design Parameter	Guarantee	Performance
SO <sub>2</sub> Removal Efficiency	93%	95-98+%
Ammonia Slip, ppm	< 10	3 – 7
Opacity	<4% from NH <sub>3</sub>	0% from NH <sub>3</sub>
Pressure Drop, “WC	< 11	7 – 8
Purity, %	99	99.5
Moisture, wt%	< 1.0	< 0.1
Hardness, %	< 5	1 – 2
Size Guide Number	240 – 290	240 - 260

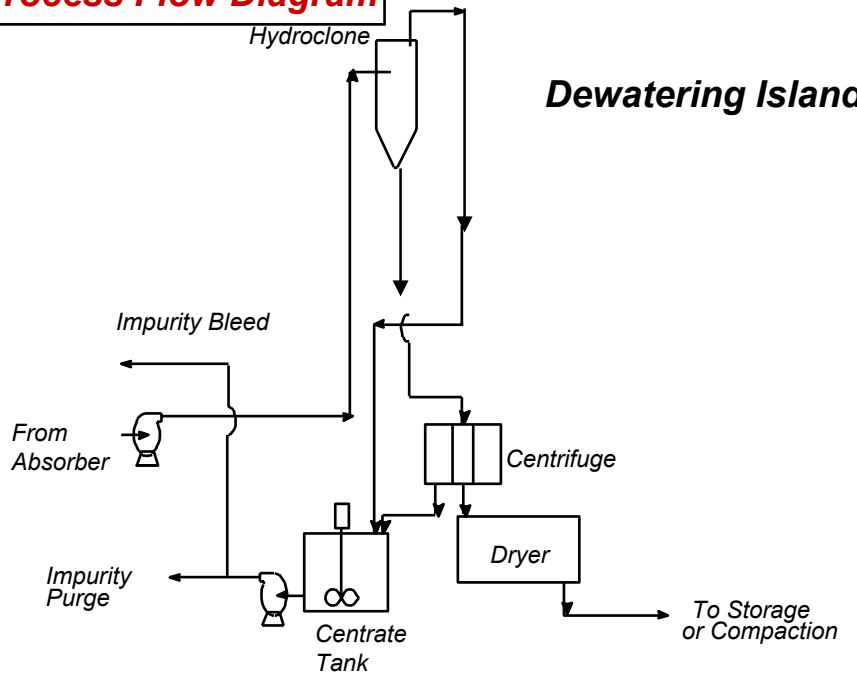


## MLX Ammonium Sulfate Process Flow Diagram

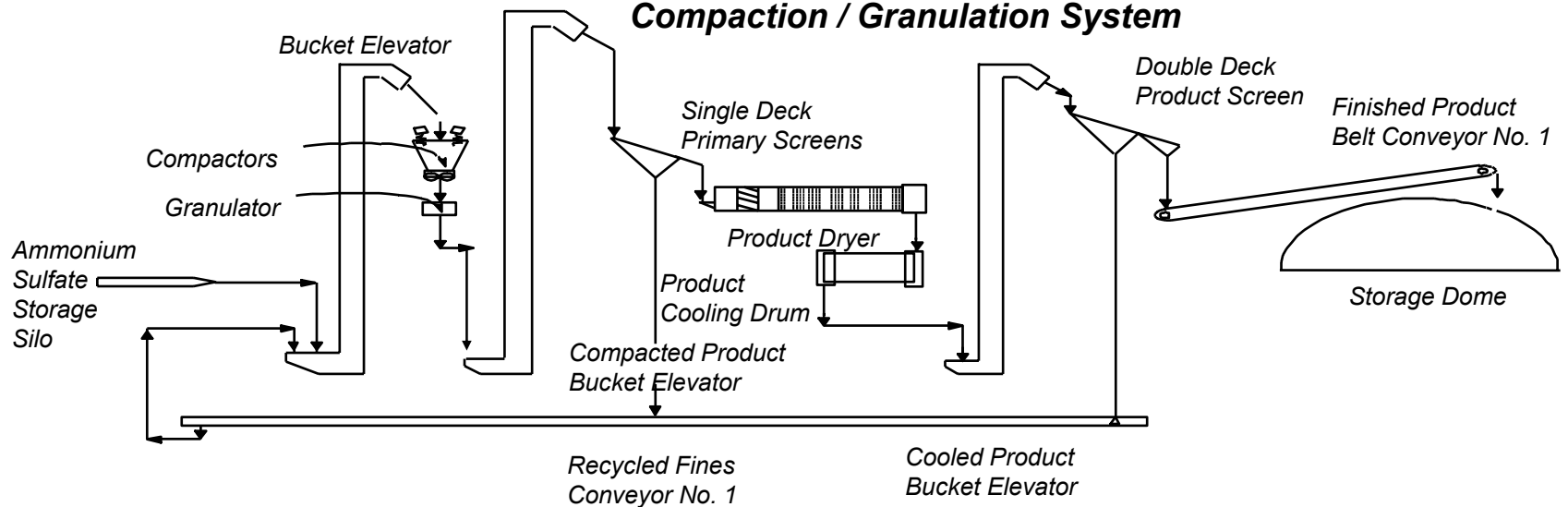
### Absorber Island



### Dewatering Island



### Compaction / Granulation System



## ***Dakota Gasification Company, North Dakota Great Plains Synfuels Plant, 350 MW***

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*Fuel.....Heavy Resid.  
% Sulfur.....5.0%  
Inlet Gas Volume  
(acfm).....1,187,000  
Reagent.....Ammonia  
Absorber Type.....Spray Tower  
SO<sub>2</sub> Efficiency Capability...98+%  
Startup Date.....1996*

*The DGC subsidiary of Basin Electric is a partner in the first application of MLX's patented ammonium sulfate FGD technology. This process produces a high value byproduct which can generate a positive revenue stream for the Owner, thus offsetting a portion of the operating expenses of the system. DGC selected the MLX process over conventional limestone scrubbing.*



# **Optimizing the Value of Ammonium Sulfate FGD Product**

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***Ammonium Sulfate is produced in two main forms:***

- Standard grade crystals which are sugar-like in appearance;***
- Granular product in the 1.0 – 3.5 mm size range depending on local preferences;***
- Standard grade can be used as feed material for ammoniated NPKS compounded products; limits application effectiveness for different crops & growing situations;***
- Granular product can be custom blended to meet exact needs of soils given their composition, previous crops and current year target crops;***
- Granular product enables farms to optimize the nutrients applied while minimizing the “non-effective” use of NPKS constituents;***
- FSU “maximum production” techniques over applied certain nutrients leading to serious runoff and water pollution problems;***
- Granularization techniques preclude the majority of such problems;***

***Marsulex's Use of Granularization Differentiates  
& Maximizes the Market Value of AS***



# ***Ammonium Sulfate Product Quality Characteristics***

## ***Purity - 99+%***

- Nitrogen - 21.0 - 21.1%
- Sulfur - 24.0 - 24.2%
- Water Insoluble Matter - < 0.1%
- Color - White to Beige
- Heavy Metals - < 10 ppm

***Exceeds Fertilizer Standard***

## ***Residual Moisture***

- Multiple Drying Steps
- Less Than 1.0 wt% Moisture
- Coated with Anti-caking Agent

***Excellent Storage & Handling***

## ***Particle Size***

- 1.0 mm - 3.5 mm
- 240 - 275 SGN
- Uniformity Index - 45 - 50

***Ideal for Bulk Blending  
& Direct Application***

## ***Hardness***

- Demonstrated Compaction Technology
- Expertise in Product Hardening Technology
- 1 - 3% Attrition in Industry Test

***Can be Handled and Transported  
Without Generating Dust***

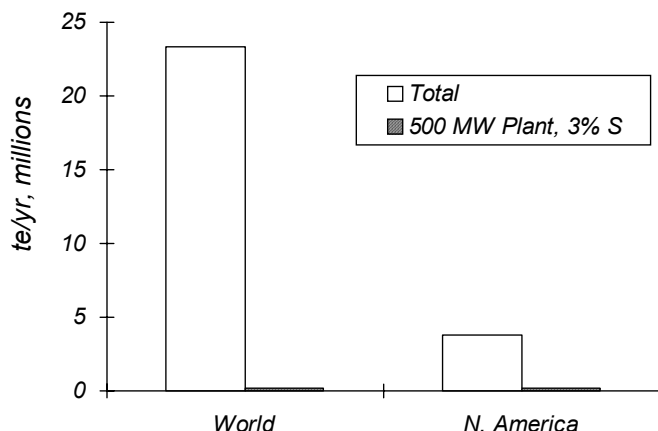
***High Quality Commercial Product!***



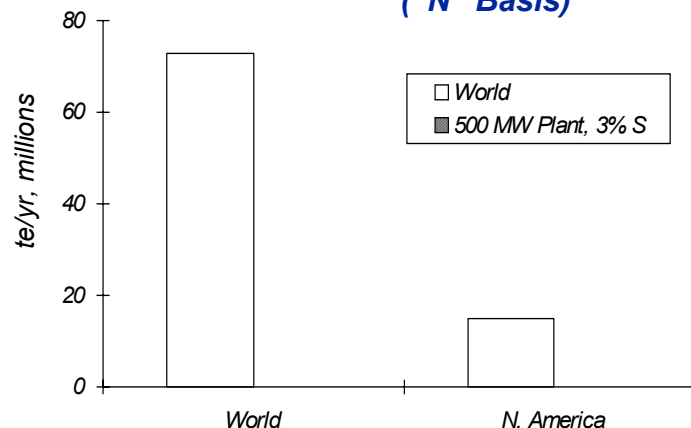
# World Nitrogen Fertilizer Market

## Ammonium Sulfate & Total Nitrogen (“N”) Basis

Ammonium Sulfate Capacity



Total Nitrogen Based Fertilizer Capacity (“N” Basis)



### Conclusions:

- Each 500 MW ammonium sulfate plant (3% S) represents approximately 3% N. American capacity and 0.6% of world capacity
- Ammonium sulfate will compete with urea, ammonium nitrate and other nitrogen based fertilizers at its “floor” value (“N” content value only)
- Once competing at “N” value, each 500 MW plant represents only 0.2% of N. American capacity and 0.04% of world capacity

**Nitrogen Market is a Solid Foundation for Ammonium Sulfate**





## ***AS Summary: Marsulex Technology Enables a Comprehensive Approach***

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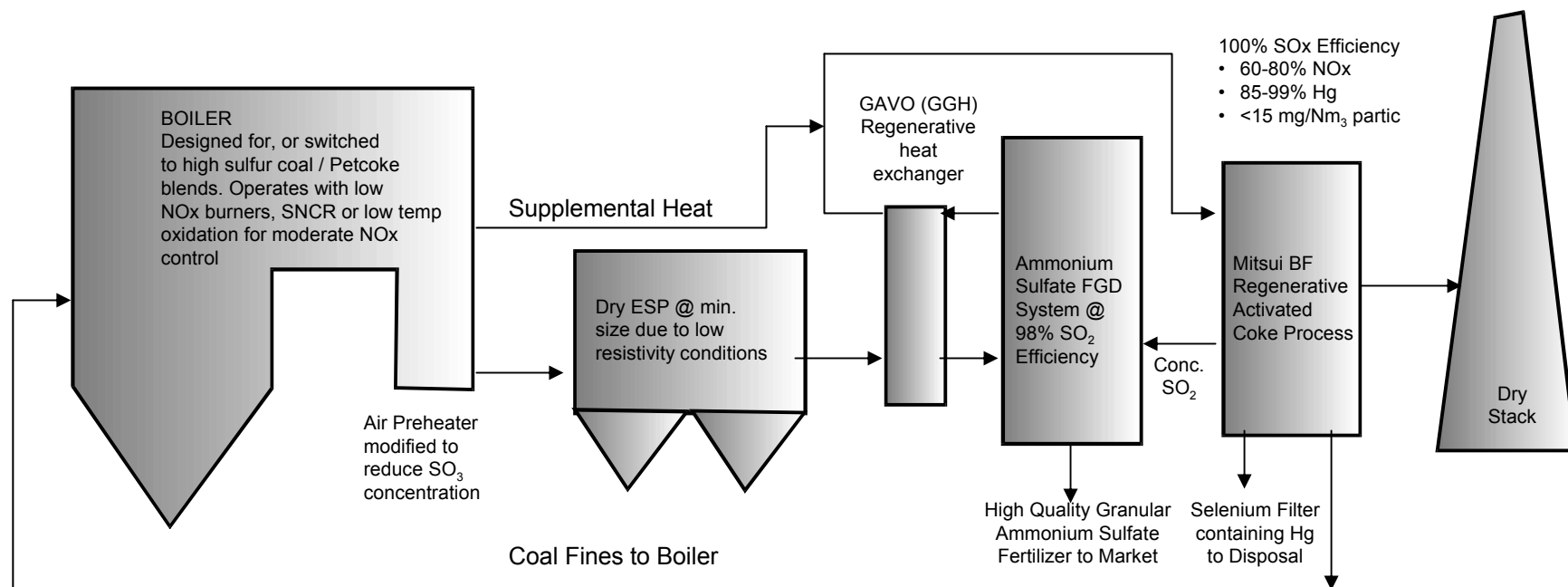
### ***Full Integration with Boiler Unit & Fuel:***

- *Ammonia technology facilitates and encourages the use of higher sulfur fuels or fuel blends;*
- *Higher sulfur fuels are typically priced lower per thermal unit of heat content than lower sulfur fuels;*
- *Lower cost fuels enables utilities operators to reduce power generation costs;*
- *Production of high quality, granular fertilizer makes maximum use of nitrogen/sulfur species;*
- *Fertilizer granularization encourages customized blending & optimum crop feeding;*
- *Ammonia technology reduces CO<sub>2</sub> emissions versus conventional technologies;*
- *Ultimately, carbon adsorption can be used to reduce Hg & organics emissions;*
- *Enables a highly beneficial, synergistic approach to infrastructure integration;*

***Marsulex AS Technology offers benefits to  
Power Producers, Refineries & Infrastructure Planners***



# Future BACT for Coal-Fired Power Plants



## Impacts:

- Significantly lower fuel costs
- Avoids SCR

Minimal Dry ESP costs

Precludes new chimney or high alloy design

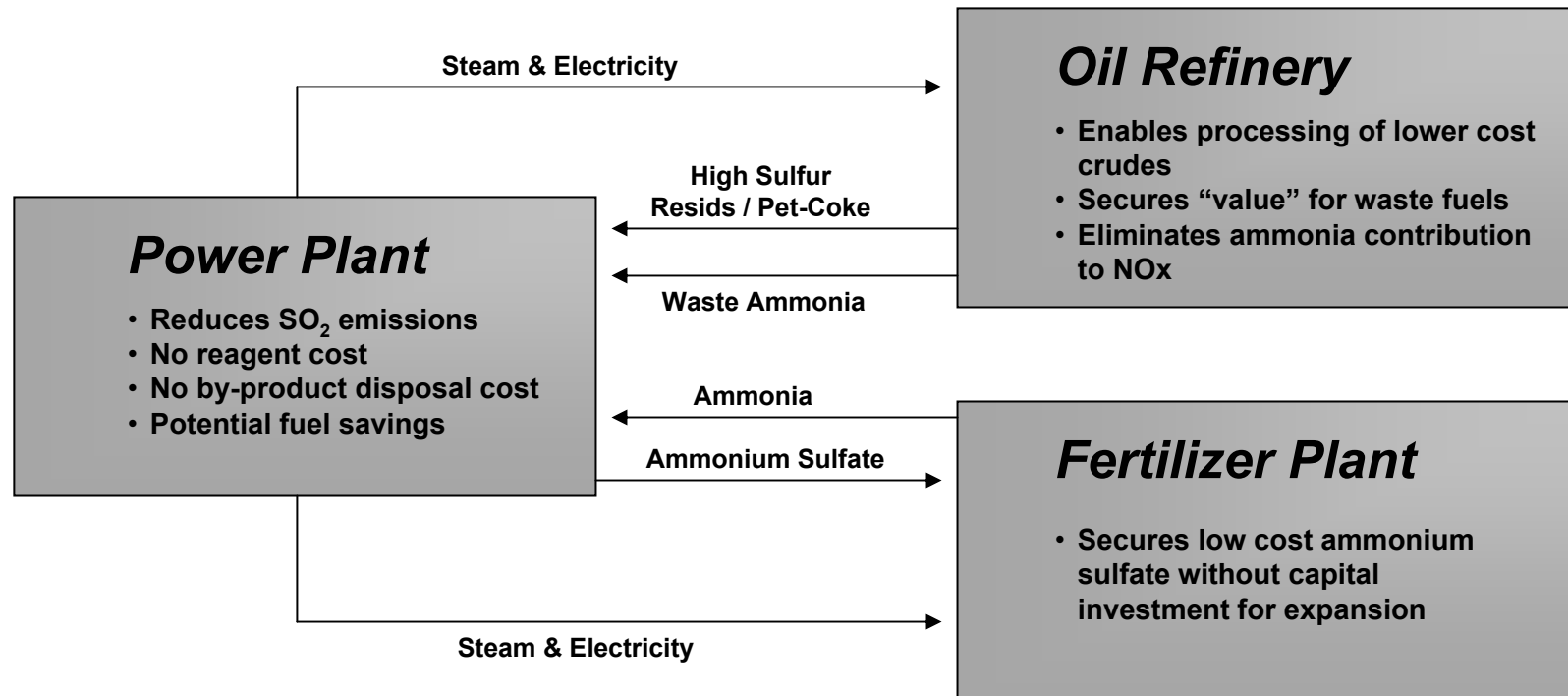
"Toll" value of AS vs. ammonia is positive

Final polishing step for residual SO<sub>x</sub>, particulate, NO<sub>x</sub> & Hg reduction

**Revenues from AS "toll" and Fuel Savings cover Total System O&M Costs**

**MARSULEX**

# Energy & Environment Infrastructure Integration



**Marsulex Technology Can Provide Benefits  
to China's Industrial Infrastructure Base**

## **Summary - Marsulex FGD Technologies & Services**

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### ***Marsulex Offers Several Benefits to its Customers:***

- ***A strong portfolio of conventional & advanced FGD technologies;***
- ***An extensive, worldwide FGD experience base exceeding 55,000 Mwe which includes a broad range of designs to meet various situations;***
- ***Continuous technological advancements resulting from R&D;***
- ***Successful history of effective technology transfer through licensing;***
- ***A proven ammonia-based FGD system whose economics thrive on applications using low cost, high sulfur fuels and which produces high quality fertilizer;***
- ***The technology to impact a country's infrastructure planning to take advantage of synergistic benefits between power, fertilizer and oil refining capacity;***

***Marsulex Technologies Provide Cost Effective Solutions  
To Power Producers & Refineries Worldwide***

